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PROCESSING - CONVENTIONAL CHROMIUM PLATE ON HIGH STRENGTH STEEL - CORROSION RESISTANT FLUID APPLIED TO - EVALUATION OF

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PURPOSE:

CF-500 crack-free chromium possesses good corrosion resistance with normally thin plating, an equal thickness of conventional chromium electroplate with its inherent fine microcracks is inadequate as a direct substitute. This test was performed primarily to determine if conventional chromium electroplate in .0020" - .0025" thickness could be used in lieu of CF-500 provided it received additional treatment for improved corrosion resistance.

A second problem involved the development of a test to determine whether parts have CF-500 chromium or conventional chromium electroplate.

The purpose of this test, therefore, is to invesigate several materials for improved corrosion protection and to develop tests to differentiate between CF-500 and conventional chromium electroplate.

SUMMARY:

Three types of tests were conducted in the Engineering Chemistry Laboratory. A summary of the test procedures, results and conclusions follow:

I Tests to determine the effectiveness of DC-15A (DC F-15A) and G. E. material number 514-1789-6 as corrosion inhibitors for inadequate thickness of conventional chromium electroplate.

Specimens of H-11 type steel were plated with .002"-.0025" conventional chromium electroplate from either a 33 or 53 oz/gal plating solution. A segment of the specimens were exposed to MIL-F-5566 anti-icing fluid to simulate a service condition. All specimens including controls were exposed to 20% salt spray by procedures described in Federal Test Method Standard 151, Method 811 for 48, 120 and 168 hour periods. Corrosion began at approximately 90-120 hours and had developed appreciably by 168 hours. An identical thickness of CF-500 crack-free chromium would pass 250 hours of salt spray with no corrosion. On this basis it was concluded the corrosion inhibitors were inadequate.

II Tests to differentiate between CF-500 and conventional chromium electroplate.

Six different methods were investigated for distinguishing or determining the extent of cracks in chromium electroplate. It was concluded that only one method, the electrolytic copper sulfate test, was effective in accentuating cracks and differentiating between the two chromium electroplates.

III Tests to determine the effects of corrosion inhibitors on simulated hinge pin bearing surfaces.

Standard test races were lubricated with X-38 dry-solid film lubricant and installed on a modified MacMillan lubricant wear test machine. Test corrosion inhibitors were dropped on the race while oscillation was in progress. A marked decrease in hours wear life was noted and it was concluded the fluids were detrimental.

PROCESSING - CONVENTIONAL CHROMIUM PLATE ON HIGH STRENGTH STEEL - CORROSION RESISTANT FLUID APPLIED TO - EVALUATION OF -

OBJECT:

1. To determine the degree of improved corrosion protection afforded conventional chromium electroplate by Dow-Corning DC 15A or General Electric's material Number 514-1789-6.

2. To develop tests to differentiate between CF-500 and conventional chromium electroplate.

3. To determine the effects of improved corrosion resistant treatments on simulated hinge pin bearing surfaces.

SPECIMENS, MATERIAL AND TEST EQUIPMENT:

I Specimens

Item	Use	Source
15 pieces 2"x5"x .040" H-11 steel	Basis metal for salt spray test specimens	Universal Cyclops Corp. Stewart Street Bridgeville, Pa.
1 piece 1/2" x 3" .040" H-11 steel	Basis metal for salt spray test specimens	Universal Cyclops Corp. Stewart Street Bridgeville, Pa.
1 piece 2"x2"x .040" H-11 steel	Basis metal for salt spray test specimens	Universal Cyclops Corp. Stewart Street Bridgeville, Pa.
21 pieces 1-1/2" x 3"x.040" H-11 steel	Basis metal for crack detection tests	Universal Cyclops Corp. Stewart Street Bridgeville, Pa.
42 standard test races No. T 54148 Code 3-223	Bearing test surface	Timken Roller Bearing Co. Toledo, Ohio

II Materials

Item	Use	Source
15 gallons of 33 oz/gal conventional chromium plate solution	Application of conventional chromium plate to test specimen	Solvay Process Division Allied Chemical Corp. 61 Broadway New York, N. Y.
15 gallons of 53 oz/gal conventional chromium plate solution	Application of conventional chromium plate to test specimen	Solvay Process Division Allied Chemical Corp. 61 Broadway New York, N. Y.
15 gallons of 44 oz/gal CF-[illegible] 500 plating solution	Application of crack-free chromium plate	Metal & Thermit Co. Rahway, New Jersey
1 pint of Dow Corning F15A Corrosion inhibitor	Test corrosion inhibitor	Dow Corning Corp. 592 Saginaw Road Midland, Michigan
1 pint of General Electric corrosion inhibitor No. 514-1789-6	Test corrosion inhibitor	General Electric Company 1 River Road Schenectady 5, N. Y.
1 quart of Parco Lubrite No. 2 MIL-C-16232 Type 1	Bearing race pretreatment	Parker Rustproofing Co. 2169 East Milwaukee Ave. Detroit 11, Texas
1 quart of Ucon Fluid	Test contaminant for bearing surfaces	Union Carbide 30 East 42nd St. New York 17, N. Y.
1 quart MIL-L-6085 oil	Test contaminant for bearing surfaces	Shell Chemical Company 308 Madison Avenue New York
1 gallon of Isopropyl alcohol (MIL-F-5566)	Test contaminant for bearing surfaces	Fisher Scientific Company 203 Fisher Building Pittsburgh 19, Pa.

III Equipment

Item	Use	Source
Heat treat furnace	Heat treating of basis metal specimens	Hevi-Duty Electric Co. Milwaukee, Wisconsin
Vapor honing apparatus	Application of electroplates and anodic treatments	Reumelin Mfg. Co. Milwaukee, Wisconsin
Salt spray chamber	Application of test environment	Industrial Pump & Filter Manufacturing Company
Hydraulic Press	Application of Uniform Pressure to crack detection test specimens	American Instruments Co. Silver Springs, Md.
Research Metallograph	Examination of crack detection test specimen	Bausch & Lomb Company 626 St Paul Street Rochester 2, N. Y.
Binocular Microscope	Examination of crack detection test specimen	Bausch & Lomb Company 626 St Paul Street Rochester 2, N. Y.
MacMillan Lubricant wear test machine	Testing wear life of finished races	Hartman Tool Mfg. Co. Los Angeles, Calif.

PROCEDURES:

Part I - Improved Corrosion Resistance Test

Specimens requiring conventional chromium electroplate were plated as indicated from either a 33 or 53 oz/gal chromium tank containing $SO_4^=$ as H_2SO_4 in a ratio of 1/100 $SO_4^=$ to 100 parts chromic acid. The tank temperature was 130 ±5°F and the plating current density was two amps/inch square. Plating thickness was .0020 to .0025".

All basis metal specimens were heat treated to a 250,000-280,000 tensile ultimate strength level and vapor honed to remove all heat treat scale.

CF-500 crack-free chromium electroplate was applied from a solution containing 44 oz/gal of CF-500 powder. The plating current density was 2 amps/inch square while the temperature was 150 ±2°F. Applied plate thickness was .0020"- .0025".

Specimens requiring treatments with the special corrosion inhibitors were dipped in the test corrosion inhibitors five minutes and wiped dry with cheesecloth. The soak in MIL-F-5566 (iso-propyl alcohol) fluid was for 15 minutes, followed by a wipe with cheesecloth. After finishing was completed specimens were subjected to a total of 168 hours by procedures shown in Federal Test Method Standard 151, Method 811 for 20% salt spray.

Part II - Development of Methods for Crack Detection Tests

A. Modified Ferroxyl Test

A solution composed of 10 grams agar, 10 grams sodium chloride, 1 gram of potassium ferrocyanide and distilled water to make one liter was made up. The solution was warmed and the chromium plated specimens were dipped in the solution for 3-5 minutes. Specimens were removed and allowed to dry in the horizontal position. The specimens were examined for a Turnbulls blue appearance in voids, cracks, etc..

B. Electrolytic Copper Sulfate Test

A solution was prepared containing 200 grams of copper sulfate, 75 grams of sulfuric acid added to sufficient water to make one liter. The test specimen was made the cathode in the solution for 1 - 2 minutes using a current of approximately 3 amps/ft square. Specimens were rinsed, dried and examined at 25, 150 and 250 power magnification for crack identification.

C. Salt - Peroxide Test

A solution was prepared containing 5.8 grams of sodium chloride, 3 cc's of 3.6% hydrogen peroxide in one liter of water. Test specimens were soaked in the solution for 4 hours, removed, rinsed and examined for cracks,

D. Electrographic Test

A solution was made up with distilled water using 5% sodium carbonate and 1% sodium chloride and a small amount of potassium ferrocyanide. This solution was used to saturate a firm type filter paper which was inserted between a test specimen and an aluminum plate. A hydraulic press was used to apply a pressure of up to 100 psi to the assembly. The test specimen was made the anode while the aluminum plate was made the cathode. A 3 volt potential was applied for 15 to 20 seconds. The specimen was examined at various magnifications for cracks.

E. Anodic Chromic Acid Test

A test coupon was made the anode in a 33 oz/gal chromium plating solution at 2 amps/inch square for 2 to 5 minutes. At that time the specimen was rinsed and examined at 25, 150 and 250 X magnification for cracks.

F. Ferroxyl Test

A 25% rag bond paper was coated on one side with a distilled water solution containing 50 grams/liter sodium chloride and 50 grams/liter agar agar and allowed to dry. At the time of test the paper was dipped into a solution of 50 grams/liter sodium chloride and applied to specimen with the agar side contacting the specimen. The paper was kept moist with the sodium chloride solution. After five minutes had expired the paper was dipped into an aqueous solution of 10 grams/liter potassium ferricyanide. The dried paper was examined for blue spots, indicating contact with and corrosion of the steel.

After the various crack detection tests had been applied to test specimens they were visually inspected on a sterioscopic microscope at 7 to 30 power magnification. Specimens were then examined on a metallograph at 150 and 250 magnification for crack definition and accentuation. Photomicrographs were made at significant intervals of magnification.

Part III. Tests to Determine the Effects of Corrosion Inhibitors

A. Preparation of Test Races

1. Standard test races (Timken Roller Bearing Co., No. T 54148 Code 3-223) were grit blasted to a matte finish using 120 mesh aluminum oxide grit.

2. After grit blasting the races were wiped in clean methyl ethyl ketone and vapor degreased in hot vapors of trichloro-ethylene. From this point on races were handled with clean cotton gloves.

3. After cooling to room temperature the races were pretreated in a solution of Parco Lubrite Number 2.

4. After pretreating, the races were rinsed in hot running water and dried in a 160°F oven for 30 minutes.

5. When cool the races were measured to the nearest .0001" and the measurement recorded.

6. The races were then placed on a rotating spindle and sprayed with the appropriate solid film lubricant.

7. The solid film lubricant coating was cured by oven baking at various temperatures to promote the curing action.

8. Dimensions were checked again after the cure cycle was complete and the race was cool to determine that the correct thickness .0003" to .0005" had been applied.

B. Testing of Races

1. The races coated with solid film lubricant as described above were tested on a modified MacMillan lubricant wear test machine operating in a 22.5° angular oscillating motion while under a 63,000 psi load.

2. As denoted in Table I a new race was used with each fluid tested. The rub shoe block was changed for every test using a new polished rub shoe each time. The fluids were dropped onto the coated test race with new dropping pipettes so that the fluid would be in the contact area of the rub shoe and the rub shoe was subsequently lowered onto the race.

3. The machine was started and a one pound weight was added every 60 seconds until a total of twenty weights had been applied to the bail rod. Running time of machine was calculated from the initial start until failure, determined by automatic stopping of the machine by a switch triggered by sufficient increase in the coefficient of friction. Wear life was determined to the nearest 0.1 hour.

RESULTS:

Table I shows the effects of various materials on the wear life of test races.

The effects of 48,120 and 168 hour salt spray on test finishes are shown in Figures 1, 2 and 3. Figure 4 is a photomicrograph of conventional (cracked) chromium electroplate while Figure 5 shows the normal uncracked plate of CF-500 chromium. Figure 6 through 12 show the results of methods A through F tests to develop crack detection methods.

DISCUSSION:

A situation had developed where the substitution of .0020"-.0025" of conventional chromium electroplate for an equal thickness of CF-500 chromium was virtually mandatory. It is known that ordinary chromium plate has many microcracks and is, therefore, only fair in corrosion resistance. A search for a wipe on or brush applied corrosion inhibitor was begun in order to improve adequately the corrosion resistance of conventional chromium electroplate.

The two materials selected and tested were Dow Corning 15A and General Electric's material #514-1789-6 fluids. Since planes in service are occasionally flushed with anti-icing fluid, a fifteen minute immersion in MIL-F-5566 anti-icing fluid, just prior to salt spray exposure, was added. In Figures 1, 2 and 3 it is evident that both inhibitor test fluids extend the corrosion resistance but minor corrosion occurs in 120 hours and extensive corrosion is prevalent at 168 hours. The immersion in anti-icing fluid obviously decreased the corrosion resistance. It is interesting to note that an equal thickness of CF-500 chromium electroplate (without the anti icing fluid dip) withstands 250 hours of salt spray as illustrated in FGT-2732.

A second problem was the identification of parts in order that those having conventional chromium might be adequately treated. Figures 4 through 12 are microphotographs of specimens after certain crack detection treatments. Figures 7 and 8 are different magnifications of cathodic treatment in copper sulfate plating solution. Note that cracks in basis conventional chromium plated H-11 steel are all identified and accentuated by the stringers of electroplated copper metal. It was surmised that the basis metal, H-11 steel, being more conductive than the conventional chromium electroplate allows segregated plating only at cracks where solution wicks through to basis metal. Crack definition and accentuation with this method was superior to others tested. It was the only method developed that appeared to show all cracks.

Being able to apply this inspection type test by brush plating techniques would be very desirable from a practical, low cost standpoint. Efforts were made to develop a brush type test but they were largely unsuccessful.

A third problem was the effects of the corrosion inhibitors on the wear life of bearing surfaces simulated by test races as shown in Table I.

It is obvious that all materials tested reduced the wear life to a considerable extent. Materials such as UCON oil, MIL-L-6085 oil and anti-icing fluid were added because they are likely contaminants.

CONCLUSIONS:

1. Very slight improved corrosion resistance can be expected from the use of DC-15A or GE 514-1789-6 corrosion inhibitors. The advantages are inconsequential.

2. A test to distinguish between CF-500 crack-free and conventional chromium plate was developed. It is the method B, electrolytic copper sulfate test.

3. Test corrosion inhibitors diminished appreciably the wear life of bearing surfaces.

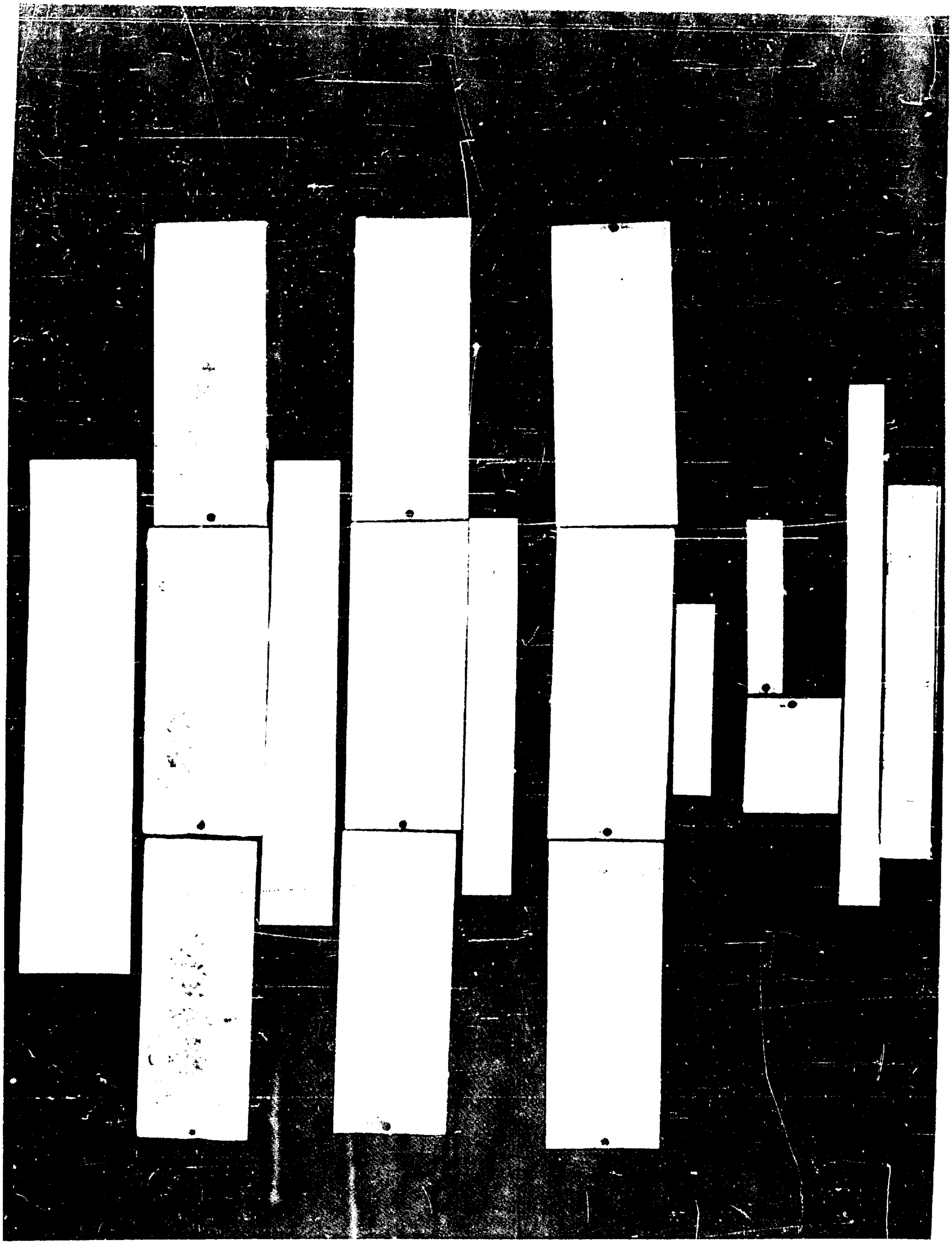
TABLE I

EFFECTS OF VARIOUS FLUIDS ON WEAR LIFE OF SIMULATED HINGE PIN BEARING SURFACES

Test Conditions

Test Machine - MacMillan Wear Life Tester
Load - 63,000 psi
Speed - 240 cycles per minute
Angular Oscillation - 22-1/2°

Specimen Number	Lubricant Applied	Test Fluid	Results Hours	Remarks
1	X-38	None	14.2	Controls
2	X-38	None	20.4	Controls
3	X-38	None	19.4	Controls
4	X-38	DC-15A	0.4	Test Fluid
5	X-38	DC-15A	0.4	Test Fluid
6	X-106	DC-15A	0.2	Test Fluid
7	X-38	UCON	0.5	Contaminant Fluid
8	X-38	UCON	0.4	Contaminant Fluid
9	X-106	UCON	3.4	Contaminant Fluid
10	X-38	MIL-L-6085 oil	0.6	Contaminant Fluid
11	X-38	MIL-L-6085 oil	0.6	Contaminant Fluid
12	X-38	MIL-F-5566	3.8	Contaminant Fluid
13	X-38	MIL-F-5566	2.5	Contaminant Fluid



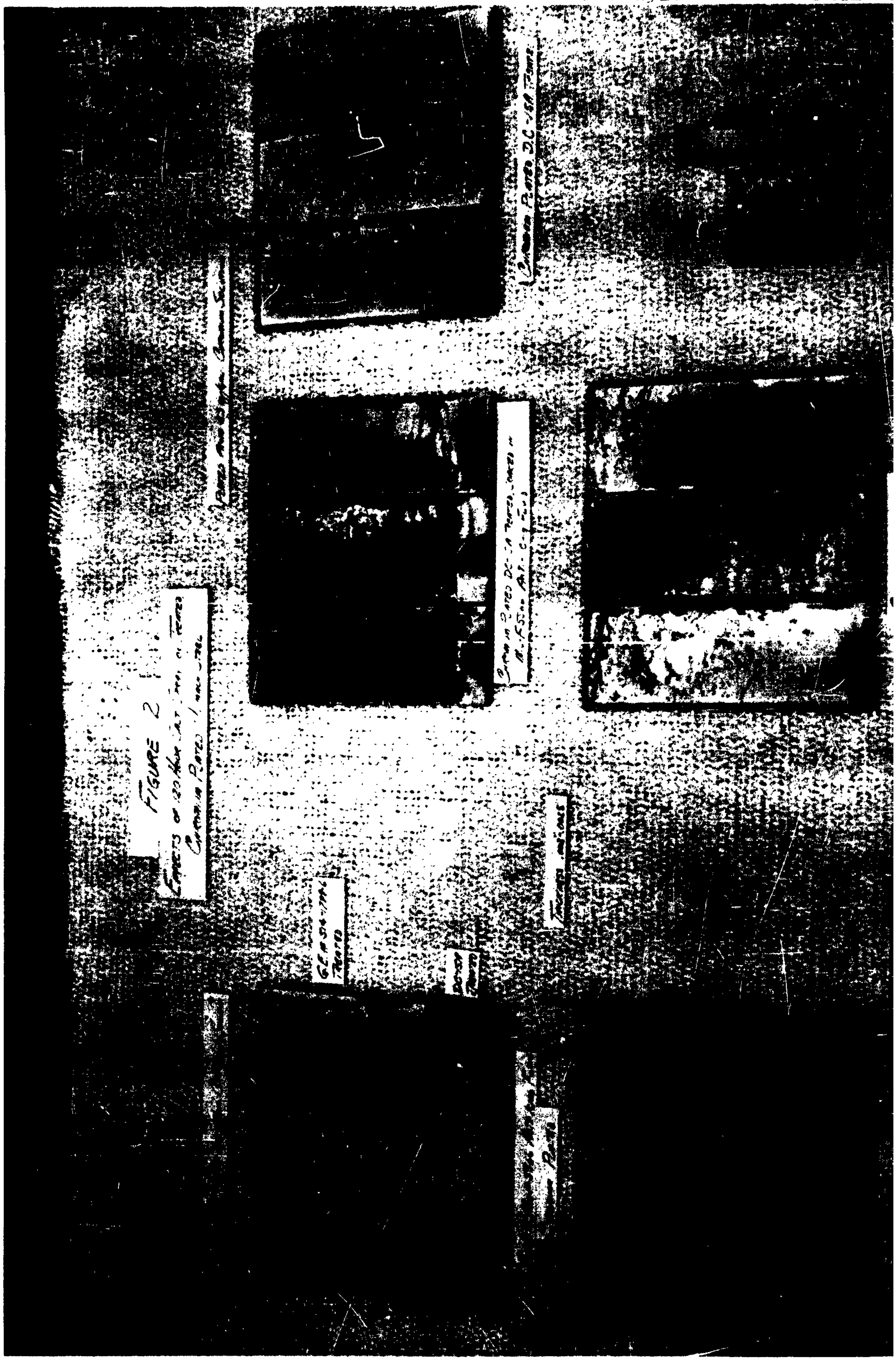


FIGURE 2

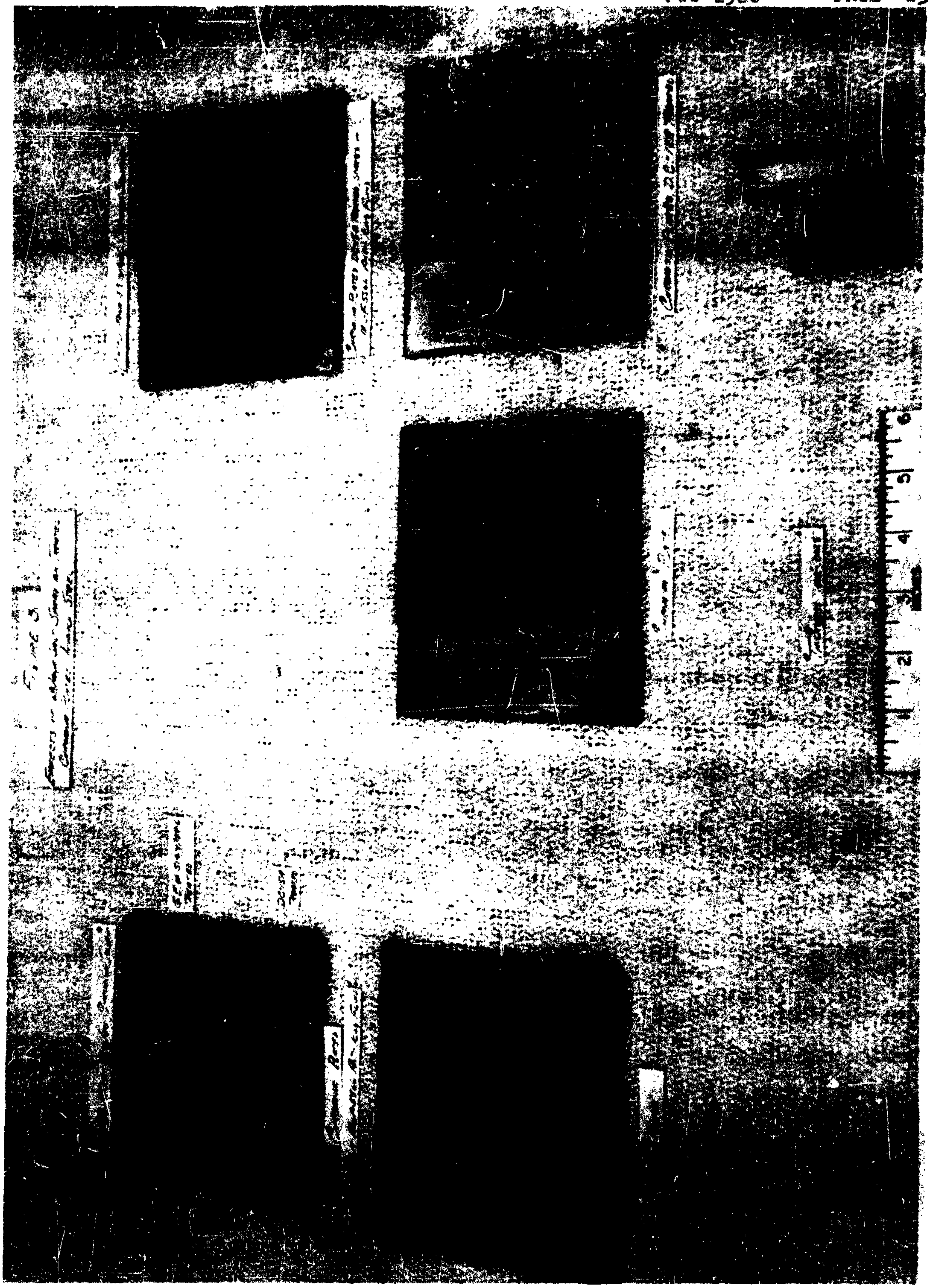
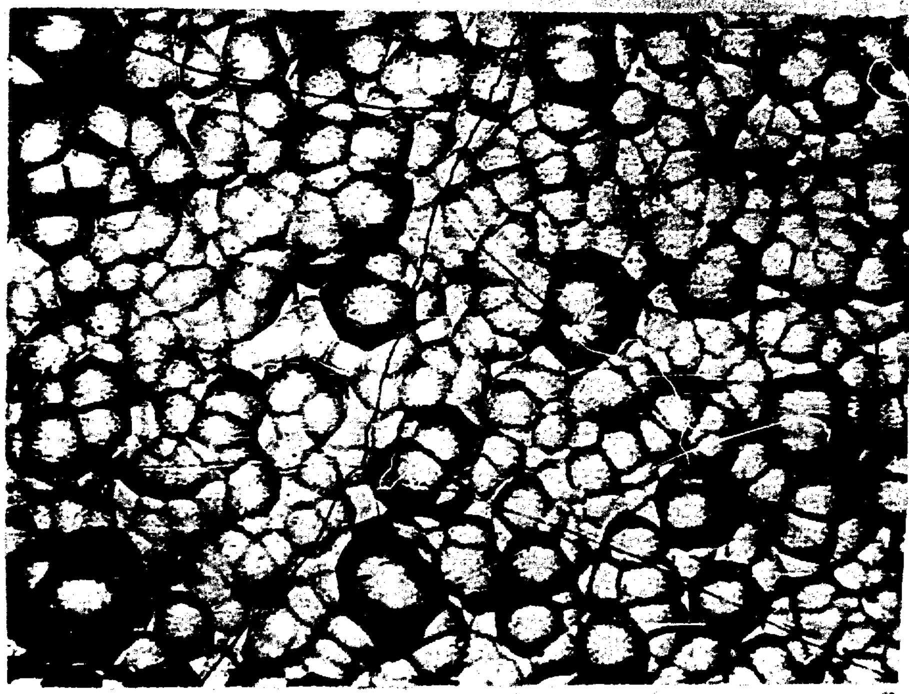
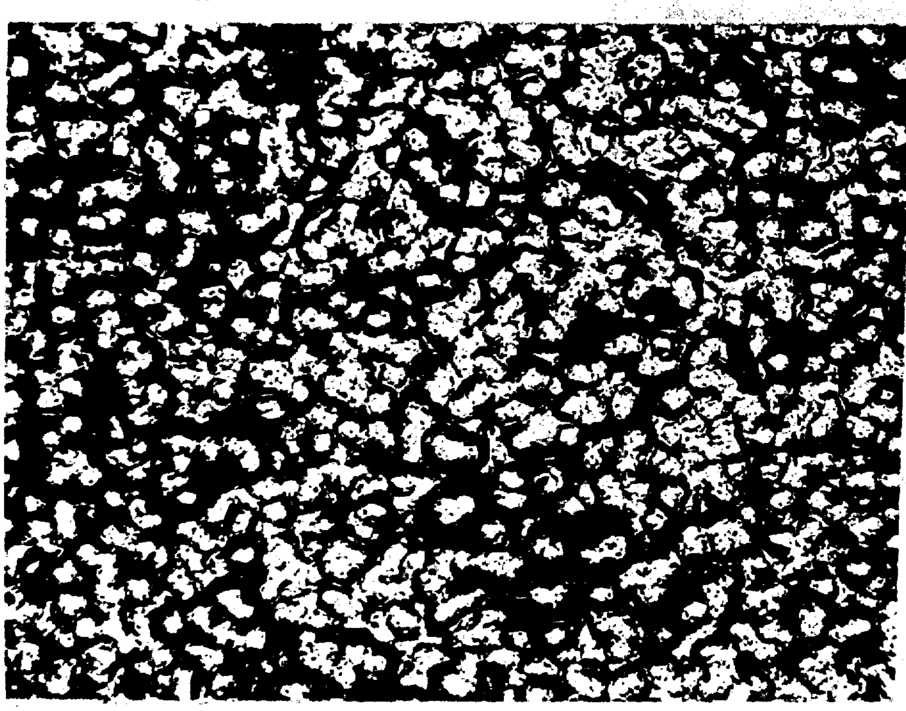


FIGURE 4



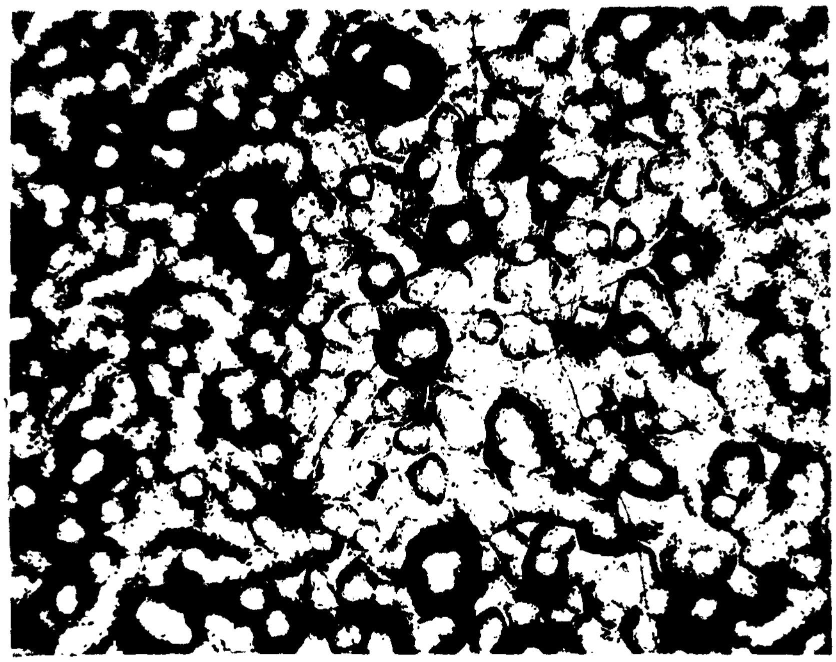
Conventional chromium electroplate showing microcracks - 250X

FIGURE 5



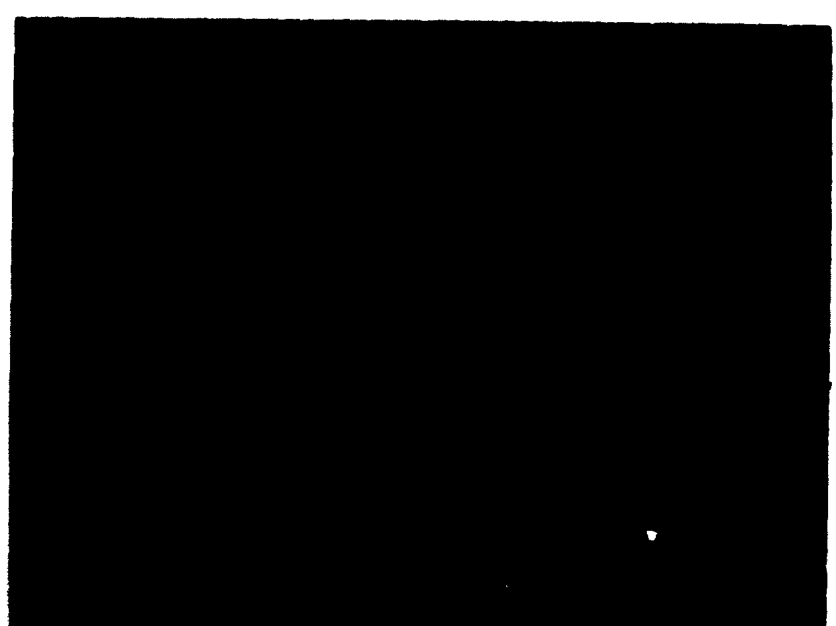
CP-500 chromium electroplate showing absence of microcracks - 250X

FIGURE 6



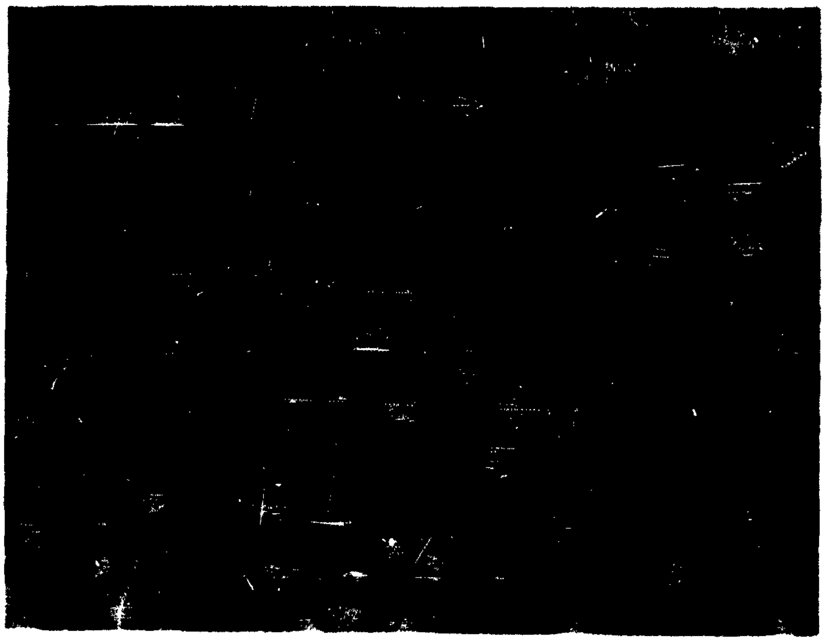
Method A, modified ferroxyl [illegible] applied to conventional chromium electroplate - 250X

[illegible]



Method B, electrolytic copper sulfate test applied to conventional chromium electroplate - 25X

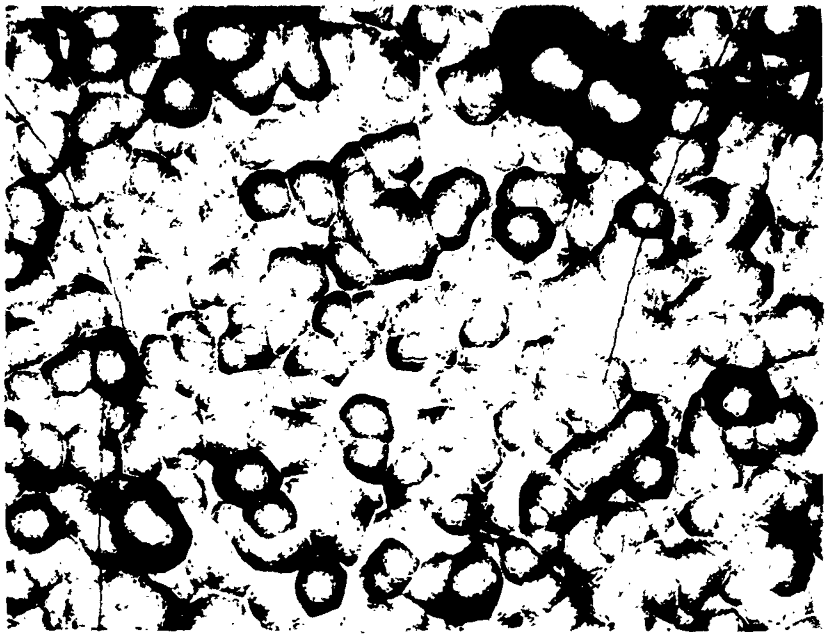
FIGURE 8



Method B, electrolytic copper sulfate test, applied to conventional chromium electroplate - 250X

FIGURE 9

Method C, salt-peroxide test, applied to conventional chromium electroplate - 250X



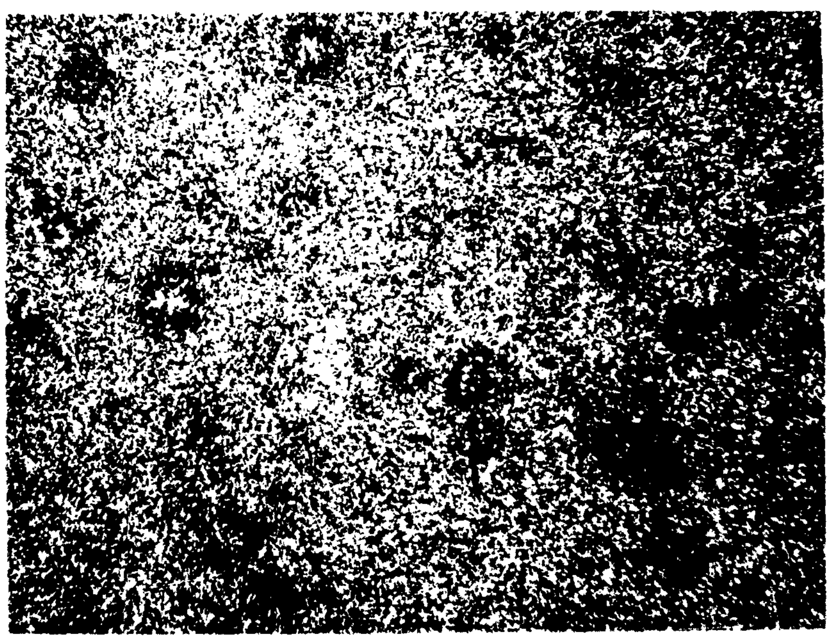
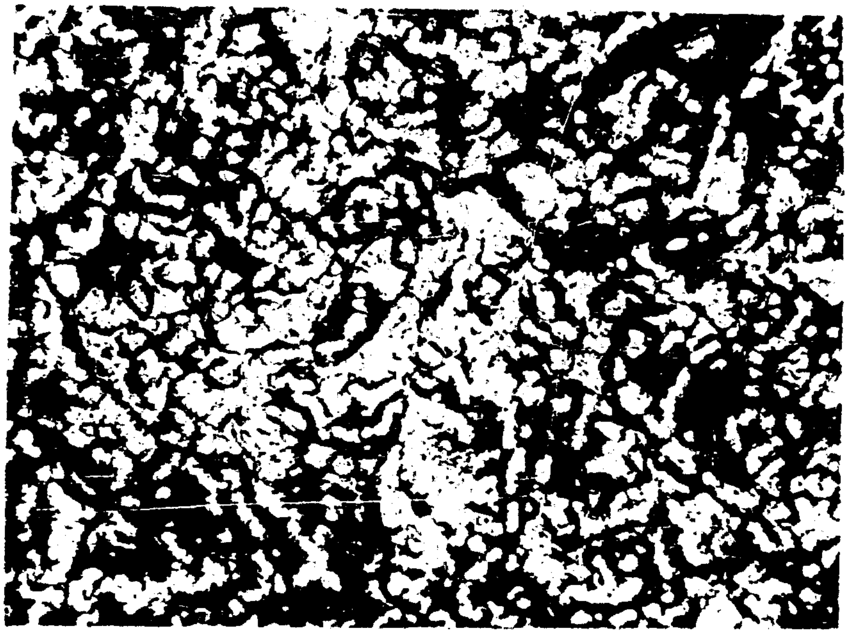


FIGURE 12



Method B, ferroxyl tests, applied to conventional chromium electroplate - 250X